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Exploring mechanisms underlying lock-in in large infrastructure projects: A management perspective

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Abstract

Research in large scale infrastructure projects have argued that the overall project performance is subject to lock-in, yet this is little understood empirically and more research is needed. Recently studies reported that lock-in can occur both at the decision-making level and at the project execution level respectively. The underlying patterns influencing project scope transformation, due to evolving expectations and/or stakeholder's perspective and the occurrence of lock-in influence in project performance. This paper explores the relationship between project scope and lock-in within large infrastructure projects in the context of cost over-run. Based on empirical data from 20 High Speed Rail (HSR) projects in Spain with multinational sets of actors, and anchored in the Management of Project (MoP) paradigm, the paper shows that a holistic perspective is essential for successful outcome. Methodologically, the paper uses data mining and a case study approach to explore mechanisms that underlie lock-in in relation with scope demarcation – tracked through contract change. It suggests that an investigation of lock-in in relationship to scope demarcation and through the lens of path dependence contributes to the understanding of cost over-run emergence. Preliminary findings highlight contract type and its content to have a great influence in cost over-run.

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1. Introduction

Large infrastructure projects such as public high-speed rail project is often a multidisciplinary endeavour where people from different professional backgrounds, e.g. engineers, technicians, economics, politics/ law and sociologists are brought together to engage in a positive outcome in terms of budgeting, time implementation etc. Large infrastructure projects, public or private, are highly risky [1], involve large investments, are characterized by long-term planning, with predetermined budget and time constraints. Too often, project scope or stakeholders' expectations change significantly over time [2] due to inaccuracies regarding costs and schedules (see e.g. [3–5]).
The potential existence of any relation between scope demarcation - timing of contractual changes, lock-in and its influence on cost overrun is an area with growing interest but which lacks empirical support. This empirical research deficiency is subject of difficult access to data, prone of poor project track record, including scattered data and due to bureaucracy and isolation of public entities and actors involved [6].

The extant literature refers to lock-in as the process of escalating commitment [7]. It is defined as "the over-commitment of parties to an inefficient project before the formal decision to build and to the inefficient specification of project after the formal decision to build has been made" [8]. Scope management, on the other hand, is fundamental in providing reliable cost and schedule programming [9], thus facilitating decision making and accountability throughout project life-span. Lock-in has been researched applying different lenses e.g. technical, political, economic and psychological yet the majority of studies are one-sided focusing on the front-end or down-stream execution without taking a holistic approach [10].

This paper presents a theoretically grounded view and argues in favor of complementarity between theories applied to the research investigating lock-in. A framework is designed based on current literature underpinning both the front-end decision making and down-stream execution – advocating a holistic approach. Recently [8] in contrast to previous position of [11] and [3], researchers argue that the concept of lock-in can be better understood from a holistic approach. While equipping this holistic perspective we aim at exploring the multifaceted context in large infrastructure project shaped by innovation, technology, complexity, pace, risk and significant uncertainties [5,12,13]. Beyond understanding we aim at promoting a balance between operational uncertainty and contextual uncertainty; to the date the dominant stream is concerned with the former – operational uncertainty: to have a clear goal and a structured technical design on how to reach it, hence isolating the project from the environment [14,15]. Why? Because goal oriented and a breakdown structure to be followed simply speaks to the logic of mankind [16,17] .

This paper attempts to answer the following interrelated questions: 1) To what extent can the transformation of project scope demarcation influence lock-in? and 2) What are some of the tensions and dynamics when lock-in occurs at the decision-making level or down-stream execution level? Anchored in the project management literature with foci in project 'actuality' [18,19], the paper adopts the 'Management of Project' (MoP) paradigm rather than project management only as execution management [20], the paper shows that a holistic perspective is essential for successful outcome. Before diving into detailed analysis searching for relationships, it is important to define cost overrun, i.e. what are the reference parameters in providing results [21]. This is due to a lack of standard definition leading to inappropriate over-run variations, hence interpreting inaccurately for the same project sample. We argue this variation is closely related to the research stream focus, e.g. front-end decision making or down-stream execution.

The paper applies an extensive research method based on two phases, analyzing the same subject thus enabling data triangulation; i.e. study sample across two phases represent the same projects. To address the first question, a literature review was conducted and data mining was used - in tracking the scope transformation via contract demarcation through data reports and its influence or relationship to lock-in emergence. In addition, an in-depth case study method is proposed deriving empirical evidence in addressing the second research question.

Apart from this introduction paper consists of 4 other sections. Section 2 provides the theoretical framework, section 3 discusses the methodology, underpinning data mining and case study research- a determinant of comprehensive empirical research. Section 4 presents preliminary analysis and section 5 preliminary findings and future focus: discussing the ongoing research.

2. Theoretical framework

The project management (PM) literature has for decades discussed the challenges associated with the implementation of large scale public infrastructure projects. Underestimation of costs at the planning stage, political sensitivity regarding costs & benefits as well as the difficulties of stopping unsuccessful projects has been recognized in the early literature [22–24]. Given the fact that control and monitoring was the primary driver behind the emergence of the discipline [20], studies were oriented in identifying factors that cause projects and programs to succeed or fail under the eminent theme 'Critical Success Factor studies' [25]. Hirschman's approach as behavioral theorist makes an exemption – the principle of 'Hiding Hand' and his ideas on the empirical context provided analytical power. Yet despite the power of thorough empirical case studies: deepening our understanding (unfortunately) his ideas have had little influence on the current PM literature. However, recently, there is a growing interest for his research and he has been considered an 'early rethinker' of PM [26].

There is not one single dominant theory in project management [27], rather the discipline uses different types of knowledge areas [10,28,29]. This pluralism – enables a comprehensive view on projects and has enriched our understanding of planning and execution. In general, the extant literature builds on two major streams revolving large scale projects under the light of over-run. The first is based on the engineering management approach and is concerned with managing down-stream execution. In this context, exploring the capability for post-decision control underpinning traditional and normative PM discipline i.e. linear, positivist oriented on "facts" (value-free), quantitative technicalities of project management aspect are favoured. Furthermore, in this research stream the focus are the application of a rational and reliable model to limit overspendings and benefit shortfalls [30], scope creep and rework mitigation exacerbating over-run [31], change orders influencing loss of productivity and their cumulative impact in project over-run [32] and the importance of design errors in cost increase [33]. At the other end, other studies exploiting the engineering management approach focus on decision-making process. These studies, recognize the complex interaction of actors involved in project and provide explanations deriving on systemic analysis [1,34–36]. Studies explore the set of causal factors instead of tracing influences of single causes, thus providing explanations on complex interactions demonstrating over-run in relation to vicious cycles caused by underestimation at the very beginning of the project. Systemic studies confront the discourse of traditional, prescriptive PM. According to [1] when project experiences over-run if conventional guides & tools are to follow the project experience greater over-run due to unrealistic schedule thus exacerbating the situation.

The second stream, studies large infrastructure projects from an organisational perspective, concerned with front – end management, focused on decision making and/or sanction only, based upon empirical research (value - laden) and derives on the following contributions: strategic misinterpretation and optimism bias [11,37,38], future perfect strategizing [39,40] and escalation of commitment [7,41,42]. In addition, within second stream large-scale projects are defined as complex undertaking but its complexities refer less to the technicalities and money involvement instead focus is rather in the substantiation features of large scale projects. Secondly, this stream defines infrastructure projects not simply as "magnified versions of smaller projects" [5] instead it claims for particular consideration on power dynamics [40], project typology [43] and stakeholder involvement [2,12].

Some researchers argue in favor of complementarity between perspectives in second stream presented above, i.e. future perfect strategizing, strategic misinterpretation and escalation of commitment goes 'hand in hand' during project life-span. [3,44] argues strategic misinterpretation consisting purposive underestimation of costs – 'delusion' is triggered from future-perfect strategizing via political power at initial stages where project idea is pitched; however, the 'delusion' must be repeated in front of stage gates – control systems, where with project maturity the skepticism and opposition grows, here escalation of commitment enables the occurrence of 'delusion' for multiple times [42]. The implications above occur especially when discussing large infrastructure projects, hence it is highly difficult to distinguish between large scale project and programs; according to [20] "a big infrastructure project can be broken down

into a number of very large sub-projects, the ensemble will have one or more shared goals, shared resources and shared benefits – the criteria for program management", as is the focus of this paper.

Some highly rational/ normative, operational and delivery oriented might consider the following a 'blasphemy': beyond second stream intrinsic complementarity, this paper argues both streams described above to be valid – the looking at large scale projects under the light of overrun through engineering management and organizations perspective respectfully. Our argument is not one of convergence between the two models, but an identification of complementarities which will enable a more comprehensive understanding of why lock-in occurs in major projects, drawing on the idea of path-dependence.

Consequently, this paper argues indeed for a bit of each stream. Moreover, anchored in the project management with foci in project 'actuality' [18,19] it emphasizes the need for broadening the scope of research in large scale projects in light of over-run, thus adopting the 'management of project' (MoP) paradigm rather than project management only as execution management.

Management of project (MoP) therefore argues the capability to manage front-end development as well as down-stream execution [20]. In particular, by adopting the research framework which builds on 'the institutional context' from [45], the paper shows how project scope and lock-in shape project performance in an contextually grounded view, see Fig. 1 below. The proposed framework thus captures front-end project definition and the influence of external environment, same as down-stream execution in the environment that project is operating thus overcoming a narrow and/or one-sided focus.

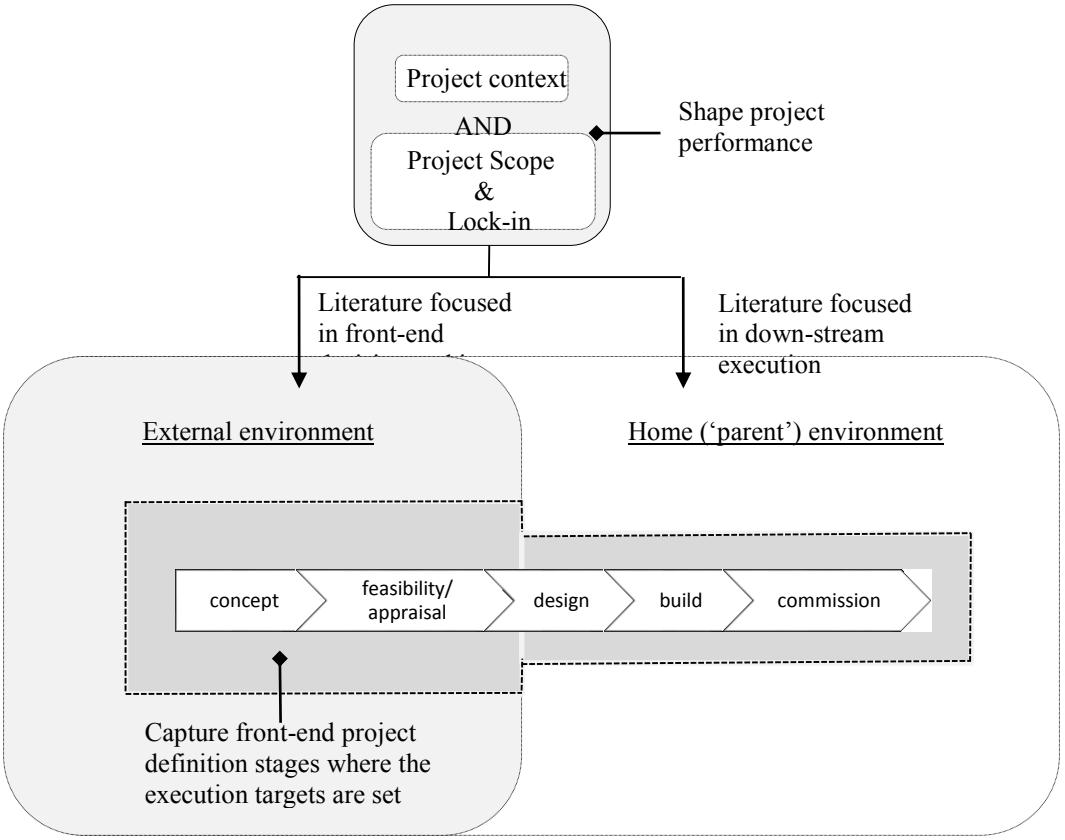


Fig. 1. Research framework – developed based on [45]

3. Methodology

3.1. Research Methodology

As discussed in the previous section project management discipline is pluralistic, i.e. research discussions are developed with several different epistemological bases, where quantitative analysis is dominant compared to interpretive and critical realist [46]. To a large extend this is what underpins the PMBOK Guide [47] and Prince2 [48] – 'method oriented' [29], seeking to establish principles and laws (see [49] for further consideration). Despite the call for pluralism in project management research, there is a lack of multi-method research published in project management journals. According to several authors [20,46,50] in relation to methodology underpinnings – methodology reflects on different paradigms, theories and it is closely intertwined with traditions of epistemology and ontology, as determinants of comprehensive research.

Project Management doesn't have its own theory as a discipline, thus the management of projects is understood through other theories [46]. Considering the lack of empirical evidence regarding lock-in and scope in large scale projects [6,8], an empirical approach is adopted based on data observation and case study research.

3.2. Research design

Research in large scale projects poses a considerable methodological difficulty [42]. The potential existence of any relation between scope demarcation - timing of contractual changes, lock-in and its influence on cost overrun is an area with growing interest but which lacks empirical support e.g. caused because of difficult access to data, prone of poor project track record, including scattered data and due to bureaucracy and isolation of public entities and actors involved (see [6] for further consideration). Resonating on the research questions presented in previous section, we suggest the research design to be carried in two complementary phases enabling data triangulation and continues comparison between data - on frequent basis:

- First phase – Extensive method based on Data mining aiming at sensing the phenomenon from an objective perspective
- Second phase – Intensive method based on Interviews & Observations: Case study research aiming for theory building

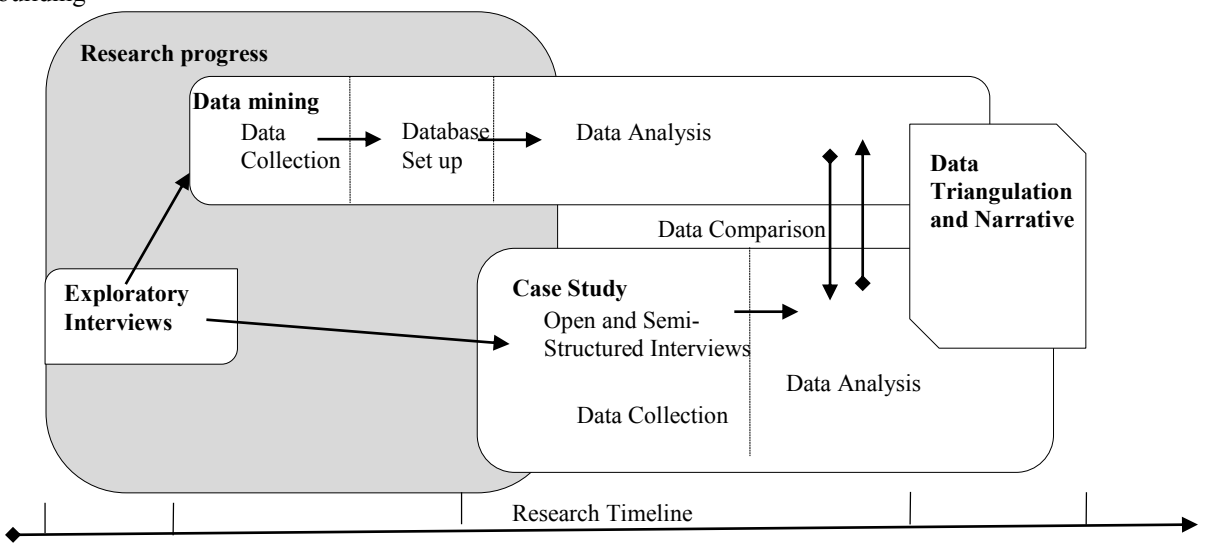


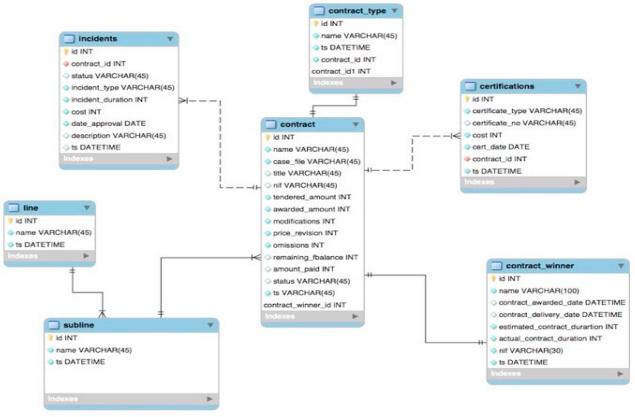
Fig. 2. Design Framework developed based on [51]: presenting an ongoing research

3.2.1. First phase

Exploratory interviews were carried in research initial with ADIF (Administrator of Rail Infrastructure) a state-owned company that works under Ministry of Infrastructure Development, Spain. The purpose of exploratory interviews was to gain an understanding and raise issues for further research. Two interviews, first with ADIF director of projects and the other with the financial manager were carried. The importance of the exploratory interviews motivates this paper emergence, as interviews revealed several controversies and helped identify contextual challenges e.g. the decision to 'stop' particular contracts on part of Ministry of Infrastructure Development – the new minister decided not to accept changes on contracts, whereas the companies acting as contractors decided to follow the legal system and dispute resolution. Through the very first interview with director of projects, we noticed a highly bureaucratic environment where the management was highly formal and little if any instinctive and this was further demonstrated when data was shared, hence consisting of scattered data with ambiguous and biased information, i.e. everyone involved in management was following guides blindly and sometime even making no-sense of the actions. The situation described above based on our first interview partially reveals the bureaucratic context [52] in a public project. The lack of reflexivity, intuition in context, 'virtuoso management' [18,53] we argue reflected in losing sense of the big picture - enabling the management for a more instinctive action and a fluid process. Throughout database design explained below, we seek to overcome such pitfalls. By adopting data mining therefore, we attempt to discover hidden patterns and relationships between project scope demarcation - timing of contractual changes, lock-in and its influence on cost overrun.

3.2.1.1. Data Mining Process

Data mining is known also as Knowledge Discovery in Databases (KDD) – "an analytical process for exploring large amounts of data in search of consistent patterns, correlations and/or relationships between variables" [54]. A portfolio consisting on a dataset was shared with us on all existing and on-going (6) High Speed Rail (HSR) lines - compiling of 20 HSR lines. ADIF develops each HSR line under program management approach. The data shared consisted on data regarding multiple contracts signed for each HSR line – program, e.g. information on tendered amount, awarded amount, modifications information in time and financial terms, delivery dates, initial estimated duration, date contracted, contract winner etc. Following [55], we developed a database underpinning the logic-process of: 'Entity Relationship Model", see fig. 3 below. Data was integrated and handled via phpMyAdmin – a tool written in PHP language.



Mapping description: **1:n** ([line-subline]; [contract-incidents]; [contract-certifications]) **1:1** ([contract- contract type]; [contract- contract winner])

Fig. 3. EER model – integrated data based on semantic information

We started with the selection of relevant data – the preprocessing e.g. removed duplicate entries, transformation and/or de-noising. The aim of data mining approach is two-fold: to develop un understanding in search of patterns and relationships between project scope demarcation and lock-in underpinning timing of contractual changes so to raise issues for further research in phase two, and to provide an effective understanding for companies to employ data mining techniques to overcome the lack of information and closure of alternatives in decision making process – leading to conscious lock-in [8].

3.2.2. Second phase

The research on the relationship between project scope and lock-in in large scale projects presents a complex and a multidisciplinary endeavor. Against the background from extant literature and first insights from phase one, on the second phase an in-depth (exploratory) analysis of two case studies was planned within management division performing in on-going HSR lines - with the aim of empirically considering the tensions and dynamics when lock-in occurs and providing an answer to second research question: "What are some of the tensions and dynamics when lock-in occurs at the decision-making level or down-stream execution level?".

3.2.2.1. Data collection

In order to dig into the "empirical" domain and uncover the mechanisms an ethnographic approach is proposed, thus providing a chance to compare the findings of phase one and between the cases per se – to discover the unanticipated [56]. Indeed, previous studies exploring the lock-in in large scale projects [8,41] adopted case based research carried through archives, periodical reports on the subject of study, direct observations and interviews – primarily open ended interviews.

As indicated above the management of ADIF uses a program approach. The adoption of case study seeks to provide analytical capability and overcome statistical generalizations [57] – providing grounds to capture the dynamism of management in project and underlying mechanisms influencing lock-in. Following the calls from normative literature also: "additional descriptive case study based research is recommended to further deprive the conditions for quantitative studies to assess the probability of overrun" [33]. A 2-3 months, in depth research study at the management division aiming at empirical data collection is based on insider/outsider approach [58], i.e. one of the authors acts as 'insider' while performing interviews and observations within management environment; other authors act as 'outsiders' offering an advantage for integrating divers perspective on empirical settings. However, the primary source of information are in-depth interviews with respondents from management division. Designed interviews were planned as 'semi-structured', comprising of 10-15 interviews per each case. Like most qualitative case studies, all interviews will be documented using manual notes, and will be recorded and transcribed accordingly. The number of interviews planned, aims not to bring credibility to the research, on the contrary study is concerned with the quality of data per se. Therefore researcher's knowledge e.g. knowledge gained from first phase – built on probing and questioning findings gradually at several stages, seeking for similarities and discrepancies: "anything but linear production of knowledge" [15].

The focus of the interviews remains respondents own experience within project. The interview questions are designed primarily as open-ended questions, with follow-up questions based on researchers 'reflexivity' aiming at acquiring deeper understanding; however, interviews always included general questions at initial e.g. "When did you joined the project?" "Describe the tasks performed in project?" "Why did the project experience overrun?"

Considering that studies are explorative in nature; the analysis of data is planned to be conducted concurrently with collection of data. To overcome subjective interpretation from the 'insider' the interview data is to be compared to direct

Interview design

1. Describe the role that governmental mechanisms play in your project? What are the specific events with regards to policy implications in decision making?
2. Describe specific events and processes encompassing the functionality of the system? Describe specific events and processes influencing the formal decision?
3. What do you think about project changes? Who disagrees with you about this, if any?
4. What are the main factors and processes influencing technical decisions and methods? What did this decision lead to?
5. What are the main factors and processes influencing schedule overrun?
6. Describe the case of possibly changing and inefficient decision involving the design of the project, if any? Who have been most influential actors involved in the process?
7. Describe the process of estimation, prior to decision level? Are there incentives promoting 'estimates accuracy', or reference class forecasting?

observations and most importantly to be triangulated with findings from phase one constantly. This iterative process of data comparison between first and second phase respectively alters both the subject and object of research – exercising conscious reflexivity from the researchers [59]. Nevertheless, authors cautiously claim on reflexivity, as 'reflexivity' is difficult concept to be determine and even more difficult to be defused in research fieldwork – providing the 'gold standard' for qualitative researcher [60].

4. Preliminary findings (First phase)

After database set-up as presented in previous section, see Fig. 3 above – content analysis is performed using SQL (Structured Query Language). This mode: content analysis – adopted in phase one, is useful in documenting trends over time, it becomes very powerful tool when combined with other research methods e.g. interview and observations: as designed in this research. Additionally, content analysis is most known for the ease of application, due to the ease and straightforward replication. However, content analysis is purely descriptive method, it describes what is there, but it doesn't reveal the underlying patterns [61], i.e. it discovers 'what' but not 'why'. The analysis is limited due to availability of material – selective reflection on reality. This software language enables complex queries to be performed, retrieving information from several data sources (see appendix A). The most powerful advantage of this software language is that it enables cross-tabulation which is useful in tracking project scope variation (through contract changes) and lock-in positions affecting project performance.

Our preliminary analysis, show that several indicators influence lock-in. Path dependence, however, plays a key role: the influence of past decisions is significant – locking-in the project into inferior outcomes. The structured indicators leading to lock-in in the literature are insufficient to capture the complexity revolving large scale projects. Our analysis provides an in-depth understanding by adding the concept of project system embeddedness in organization, in space and time. Through a processual view, the work highlights, how the relationship between project scope and lock-in shapes project performance.

4.1.1. Define cost over-run

Previous research focused in front-end decision making considers the difference between forecasted cost (estimated budget at the decision to build) and actuals cost (cost at the time of project completion), thus presenting 'dramatic' performance analysis [43,62–65]. To illustrate it when rail projects are objective of study similar to this paper focus, [65] reports an over-run of 216% for projects located in Italy, [43] an over-run of 11%. Several authors (purposively) provide vague description of their parameters – in order to exacerbate large scale project performance [65].

On the other hand, research focused on down-stream execution suggest the difference between original contract value (contract award) and actual cost. In addition we argue the process execution to be treated as 'process of goal formation' (see [14] for further consideration), thus enabling a better understanding. We further argue a need to dig deeper into underlying patterns influencing large scale project performance (as we aim thorough second phase), accordingly the challenge in managing large-scale projects are immense yet little understood [42].

Based on the discussion presented above, below are limitations from extant literature this paper seeks to overcome:

- Embracing the management of projects perspective (MoP) – understanding and recognizing the influence of front-end decision making instead of reporting from an isolated perspective e.g. as down-stream execution research does.
- Embracing the management of projects perspective (MoP) – exploring and recognizing the influence of down-stream execution before reporting from an inclusive perspective.

4.1.2. Preliminary data analysis based upon contract type

Instead of generalizing from the data, we aim to identify potential correlation project scope and lock-in in large scale projects in light of over-run based on the contract type. We have identified the following contract types in our portfolio of analyses: Assistance & Consultancy, Building & Construction, Services, Supply of goods, Others etc. Below figure 4 identify percentage of cost & schedule overrun per contract type.

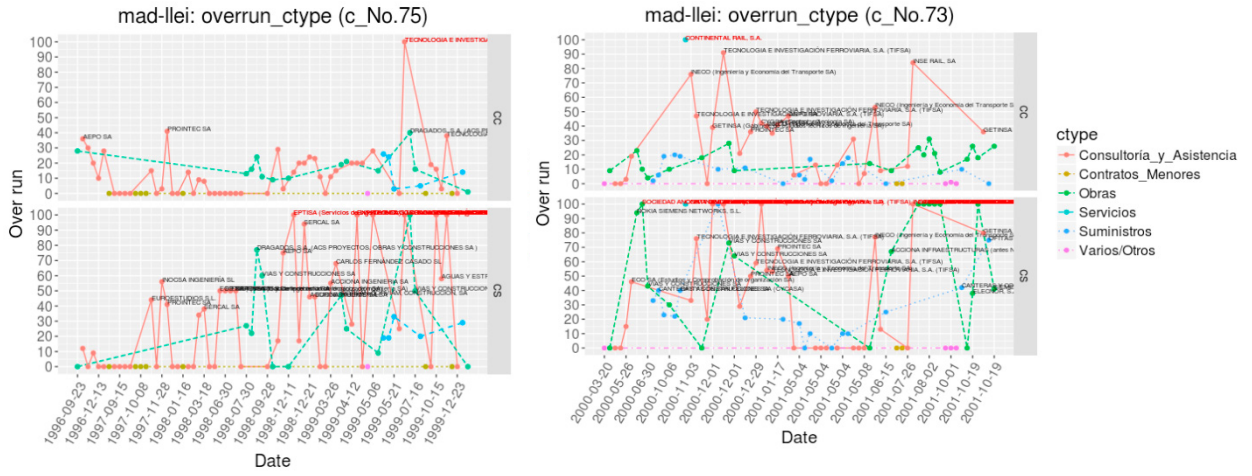


Fig. 4. Overrun per contract type within Madrid – Lleida HSR subline

5. Conclusions, implications and further research

Preliminary conclusion deriving mainly on first phase findings presented on the section above are as follows: each of the existing theories in reference to lock-in grounded on technical, economic, psychological and political patterns possess a certain amount of explanatory power. The research encourages a holistic perspective, i.e. an integration of the theoretical lenses dealing with lock-in in face of overrun and is committed to further research focusing on decision making process and down-stream execution. This puts the suggestion of [37,66] that strategic misinterpretation & optimism bias, and project cultures [3] as dominant explanation of cost overrun in a new light.

At the other end, by adopting data mining, this paper presents an opportunity for the data to be transformed into a valuable source, in discovering interesting patterns and extracting useful knowledge. A large amount of data is kept by actors involved in contractual transactions in copies, yet "the real value of storing data lies in the ability to exploit useful trends and patterns in the data to meet business or operational goals as well as for decision support and policymaking" [54]. From the management perspective, developments in business landscape focus on the use of information as a key competitive tool, yet the potential deriving on the data information presents a challenge for the firm – due to traditional method of data analysis: as encountered in our study case. Drawing on the following findings from the data presented: existence of tunnels in major contracts: HSR 15, 17, 18 exacerbates the issue, thus particular analysis is planned in this direction. As per 'Assistance & Consultancy' contract: schedule overrun has an influence and lock-ins should be explored in this correlation further - in the second phase. Finally, findings based on contract winner: set basis for 'opportunistic contractor behavior' i.e. contractors bid low and get their earnings on 'project changes' [6,67]. This again puts strategic misinterpretation and commitment perspectives respectively on: 'contractors provide a convenient scapegoat' into new light.

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